ABSORPTION COOLING OPTIMIZES THERMAL DESIGN FOR COGENERATION
Rice University

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ABSTRACT

Contrary to popular concept, in most cases, thermal energy is the real VALUE in cogeneration and not the electricity. The proper consideration of the thermal demands is equal to or more important than the electrical demands. High efficiency two-stage absorption chillers of the type used at Rice University Cogen Plant offer the most attractive utilization of recoverable thermal energy. With a coefficient of performance (COP) up to 1.25, the two-stage, parallel flow absorption chiller can offer over fifty (50) percent more useful thermal energy from the same waste heat source--gas turbine exhaust, I.C. engine exhaust and jacketwater, incinerator exhaust, or steam turbine extraction.

INTRODUCTION

The value or availability of the cogeneration alternative is not always discernible to those in search of energy and economic optimization. Such was the case at Rice University in 1983, when they started considering the need for two thousand additional tons of air conditioning for their central heating and cooling plant. The consulting engineer considered the following alternatives:

1. Electric centrifugal
2. Steam turbine centrifugal
3. Direct fired absorption--two-stage absorption
4. Cogeneration with steam two-stage absorption.

The fourth alternative--cogeneration--turned out to have the highest initial capital cost but also offered the greatest return on investment (ROI). Though Rice had both steam turbine and electric centrifugal chillers in operation, additional units would offer a negative or zero ROI respectively.

If Rice University comes to cogeneration by the "back door" so to speak, what does the "front door" look like? Cogeneration by other names has been around since the early days of the industrial revolution. In 1900 there was over 3000 MW cogenerated electricity. By 1970, this number had risen to 7000 MW. Currently, there is approximately 28,000 MW of cogeneration and that number is projected to double by the year 2000--according to the American Gas Association. The market research firm of Frost & Sullivan predicts the cogeneration market through the year 2000 will require at least $3 billion in equipment, an equivalent amount in engineering, construction and consulting, and $1.5 million for operations and maintenance cost (excluding fuel).

There are few cases--using fossil fuels--where the gross cost of generating electricity independently is less than what the local utility is selling it for. It is almost always the volume and value of the waste heat which ultimately determines the economic viability of the cogeneration investment whether it's a giant Gulf Coast chemical plant using high pressure steam, or a small motel generating air conditioning and domestic hot water. It was the efficiency of the two-stage, parallel flow absorption chillers which made cogeneration attractive for Rice University.

SYSTEM DESCRIPTION

The thermal requirements of the Rice utility system were steam at 250 psig as well as chilled water at 44 degrees F. For this reason, it was decided to use a heat recovery boiler to make steam off the gas turbine exhaust and put this steam directly into the distribution manifold along with the two remaining 25,000 pph gas fired package boilers. The choice of the gas turbine was predicated not only by price, fuel efficiency, parts and service availability, and noise, but also by its steaming or recoverable heat rate. The chosen gas turbine was rated at 3.45 MW (ISO), 15,037 BTU/KW(LHV), and 25,000 pph @ 250 psig. Under actual operating conditions, the unit can produce over 30,000 pph--See Figure 1.

The gas turbine generator is paralleled with the local electric utility through the main distribution switchboard in the central plant. The controls are set so that, at no time can the load on the generator exceed 90% of the campus demand. Because of University restrictions, no power can be sold to the utility so it is important that the power plant be a net importer of electricity rather than have import-export. This also made

Proceedings of the Third Symposium on Improving Building Systems in Hot and Humid Climates, Arlington, TX, November 18-19, 1986

dealing with the utility easier since there was no "buyback" rate to negotiate.

The selection of absorption chillers was the key to overall operating efficiency of the system. Had conventional single stage chillers been chosen (18 to 20 lb/ton), then the recovered steam from the turbine would only have produced 1200-1300 tons--far less than required. If two-stage, series flow absorbers had been chosen (12.5 lb/ton), then the required 2000 tons could have been produced but there would have been no steam left over for other small system requirements, and one of the gas fired boilers would have had to have been on line all the time. Not only that, but the two-stage, series flow absorbers were physically too big to fit the limited space available in the existing central plant and would have required a separately constructed facility at a substantial cost premium. The two-stage, parallel flow absorbers chosen had a steam rate of 9.7 lb/ton leaving approximately 5000 pph for steam system use. The two 1000 ton chillers fit snugly into the space available within the central power plant.

ABSORBER

The technology of absorption is old. It was invented in 1777, and the first commercial chiller was patented in 1860. Since then, absorption technology grew in the United States until in 1973 when the cost of fuel started to spiral. At that time, 40% of all large tonnage (100 tons & over) air conditioning in the United States was by absorption. In Japan however, the energy crunch had started earlier and in 1967, the Japanese put their first high efficiency two-stage parallel flow chiller into commercial operation. The coefficient of performance (COP) of these new two-stage units was 1.05 then compared to COP's of .6 for single stage absorbers and .95 for the two-stage absorbers in this country. Since then, major strides in metallurgy, design and manufacturing have increased the COP of the steam two-stage, parallel flow absorbers to as high as 1.34 (8.9 lb/ton).

The operation of the two-stage, parallel flow absorbers is shown in Figure 2. Steam at 114.7 psig is introduced into the first stage which brings the temperature of the diluted lithium bromide solution up to 300-310 degrees F. The refrigerant (water) is vaporized and driven off at 195 degrees F. This hot vapor is then moved to the second stage generator where the sensible heat and the latent heat of vaporization supply energy to heat more diluted lithium bromide solution and drive off more refrigerant vapor. The condensed vapor from the first stage and the vapor from the second stage are condensed and cooled in the condensor. The cooled refrigerant liquid is flowed into the evaporator where a change in pressure reduces its temperature to 39 degrees F. The cold refrigerant is pumped through special stainless steel spray nozzles over the evaporator tubes and absorbs the heat from the cooling water load. As the refrigerant is warmed by this heat, it vaporizes.

Concentrated lithium bromide from the first and second stage generators is sprayed and cooled over the absorber tubes. The refrigerant vapor from the evaporator is absorbed by the lithium bromide solution, thereby making it more diluted. The diluted solution of cooled lithium bromide is now ready to be pumped back to the first or second stage generators to start the process all over again.

There are several high efficiency heat exchangers on the chiller which use the hot, concentrated solution of lithium bromide from the first and second stage generators to pre-heat the cool, diluted lithium bromide on its way from the absorber back to the hot side of the first and second stage generators.

VALUE OF RECOVERED HEAT

If we consider the cost of fuel at $4.60/MCF (1040 BTU/CF) and utility electricity at $.065/KW, then the value of the total recovered heat is as follows:

Table 1

	Single Stage	Two-Stage Series	Two-Stage Parallel
BTU/Ton(MBTU)	19	12.25	9.7
Steam Available = 25000#/HR			
A/C Produced (T)	1315	2000	2000
Steam for Process (#/HR)		500	5600
VALUE			
A/C @ Elec. ($.045/T-HR)	$59.83	$91.00	$91.00
Steam ($5.75/M LB)	0.00	$ 2.88	$32.22
TOTAL PER HOUR	$59.83	$93.88	$123.20

Because of the load cycle at Rice, the minimum load on the chilled water system is 800-1000 tons during the winter. The cogen chillers will have an annual load factor of greater than 90%. The two-stage parallel flow chillers show an additional annual savings--or increase in ROI--of over $200,000/YR compared to the next best consideration.

CONCLUSION

The gas turbine-chiller installation at Rice University is a perfect example to dispel the myth that "cogeneration is primarily for the production of electricity to use and sell the excess to the utility." The thermal needs for a facility dictate not only the power equipment selection--gas turbine, I.C., engine or steam turbine--but also value consideration for heat recovery. Rice University is optimizing its thermal recovery opportunity by using the two-stage, parallel flow absorption chillers. High thermal efficiency and operational flexibility have replaced the shortcomings of 1960-70 vintage absorption chiller technology. This new advancement in absorption chillers adds greatly to cogeneration's successful march into the twenty-first century.

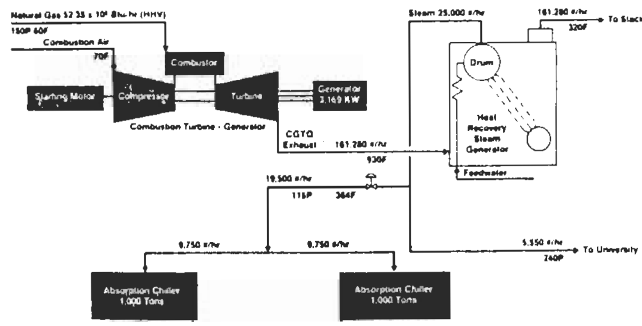

Figure 1. Institutional cogeneration project process flow diagram.

Figure 2.